US009290006B2

(12) **United States Patent**
Itagaki

(10) **Patent No.: US 9,290,006 B2**
(45) **Date of Patent: Mar. 22, 2016**

(54) **IMAGE FORMING APPARATUS FOR MEASURING THE COLOR OF A MEASUREMENT IMAGE**

(71) Applicant: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(72) Inventor: **Tomohisa Itagaki**, Abiko (JP)

(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 76 days.

(21) Appl. No.: **14/058,659**

(22) Filed: **Oct. 21, 2013**

(65) **Prior Publication Data**

US 2014/0112672 A1 Apr. 24, 2014

(30) **Foreign Application Priority Data**

Oct. 23, 2012 (JP) 2012-234025

(51) **Int. Cl.**
G03G 15/00 (2006.01)
B41J 2/21 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/2107*** (2013.01); ***G03G 15/5062*** (2013.01)

(58) **Field of Classification Search**
CPC G03G 15/5062
USPC 399/15
See application file for complete search history.

(56) **References Cited**

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2013/0094040 A1* 4/2013 Tomii 358/1.9

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Primary Examiner — Walter L Lindsay, Jr.
Assistant Examiner — Ruth Labombard
(74) *Attorney, Agent, or Firm* — Canon USA Inc. IP Division

(57) **ABSTRACT**

An image forming apparatus includes a fixing unit configured to heat and fix a measurement image formed by an image forming unit to a sheet, a measurement unit arranged downstream of the fixing unit in a conveyance direction of the sheet and configured to measure color of the fixed measurement image, a conversion unit configured to convert a measurement result of the measurement unit into a measurement result at a predetermined temperature based on conversion setting information set in advance, a setting unit configured to set a mode for generating the conversion setting information, and a generation unit configured to generate the conversion setting information by causing the image forming unit to form the measurement image on the sheet, causing the fixing unit to fix the formed measurement image, and causing the measurement unit to repeatedly measure the fixed measurement image in response to setting of the mode.

19 Claims, 9 Drawing Sheets

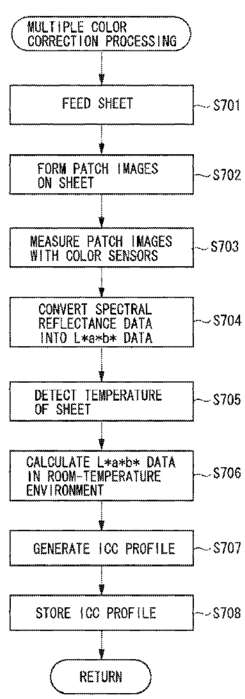


FIG. 1

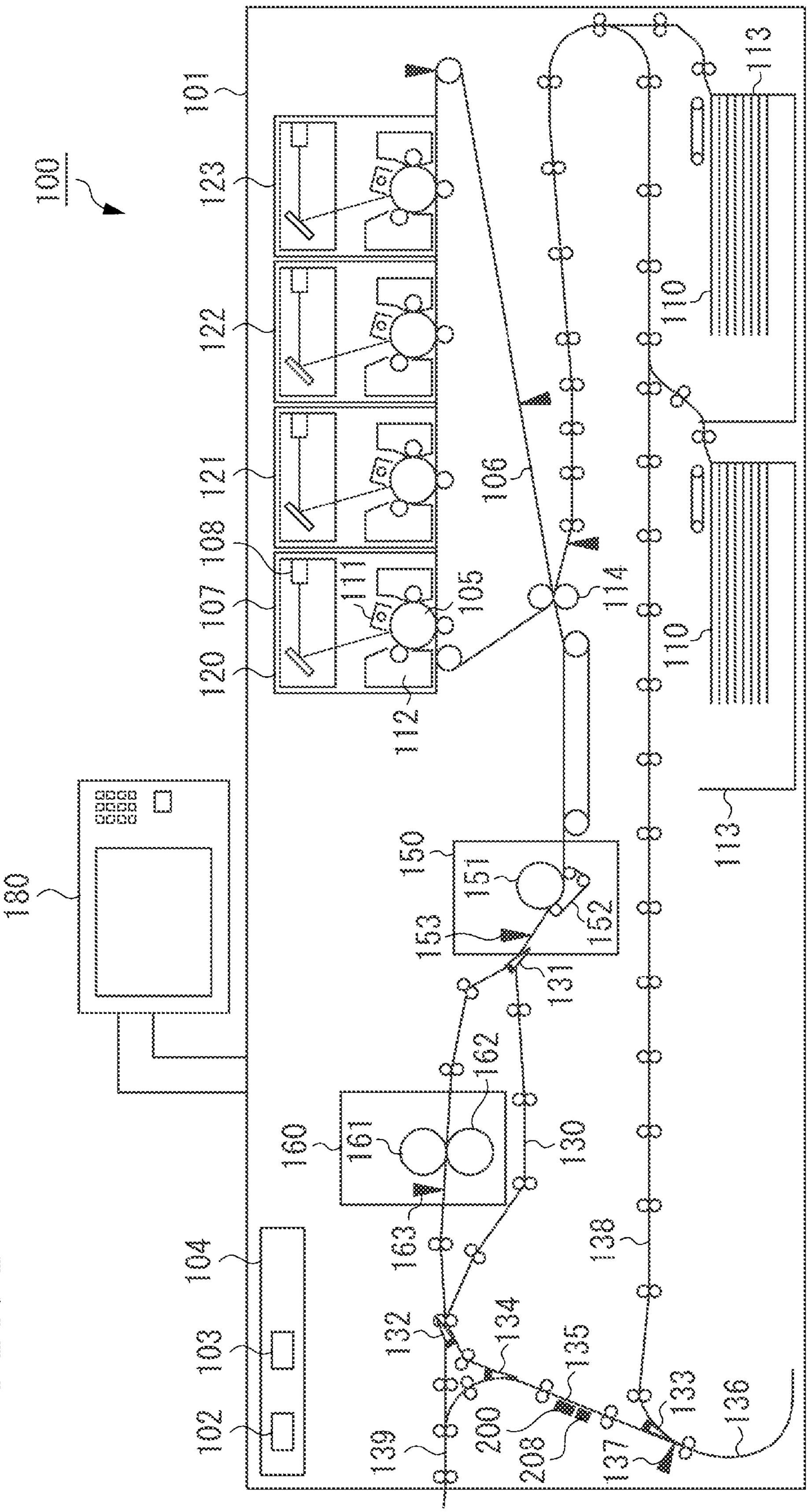
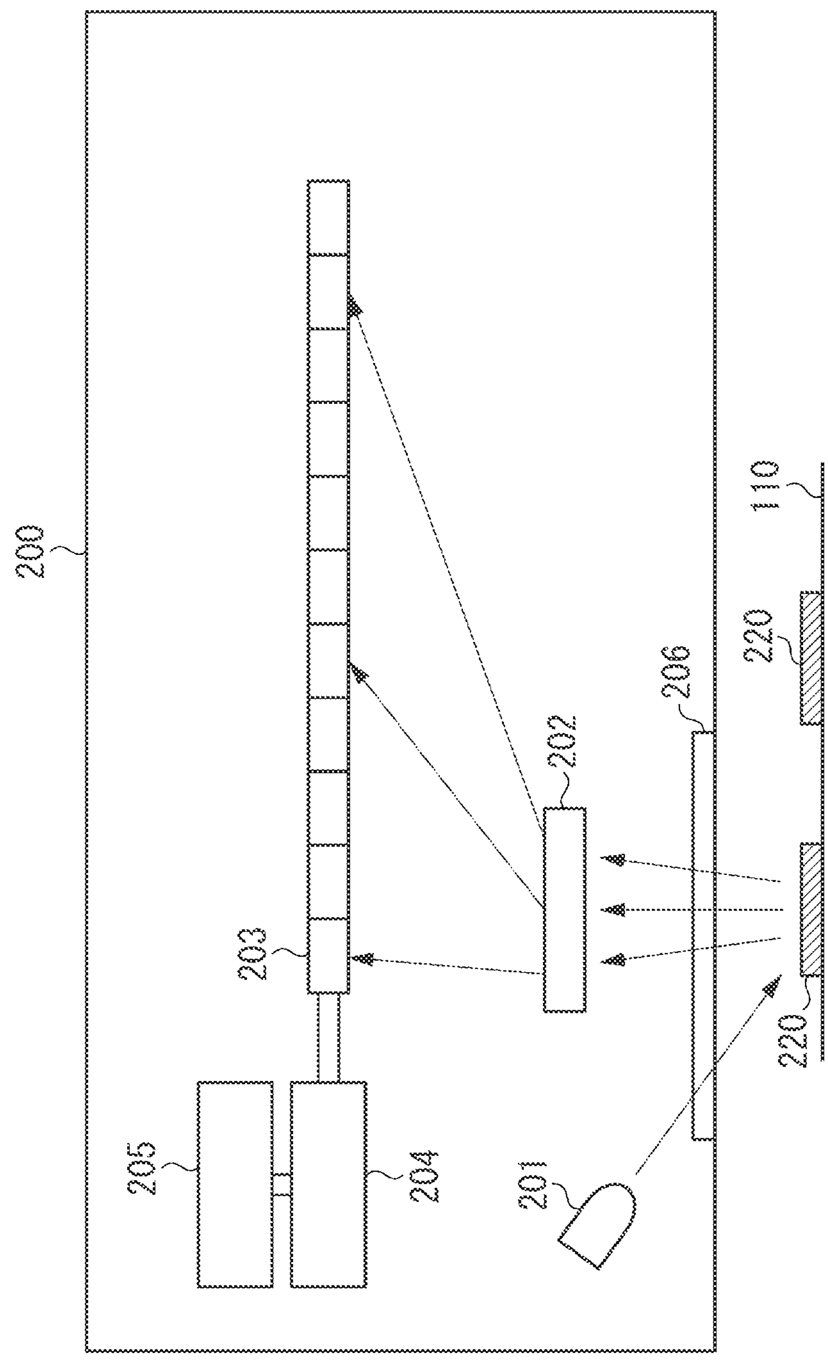

100
101
102
103
104
105
106
107
108
110
110
111
112
113
113
114
120
121
122
123
130
131
132
133
134
135
136
137
138
139
150
151
152
153
160
161
162
163
180
200
208

FIG. 2



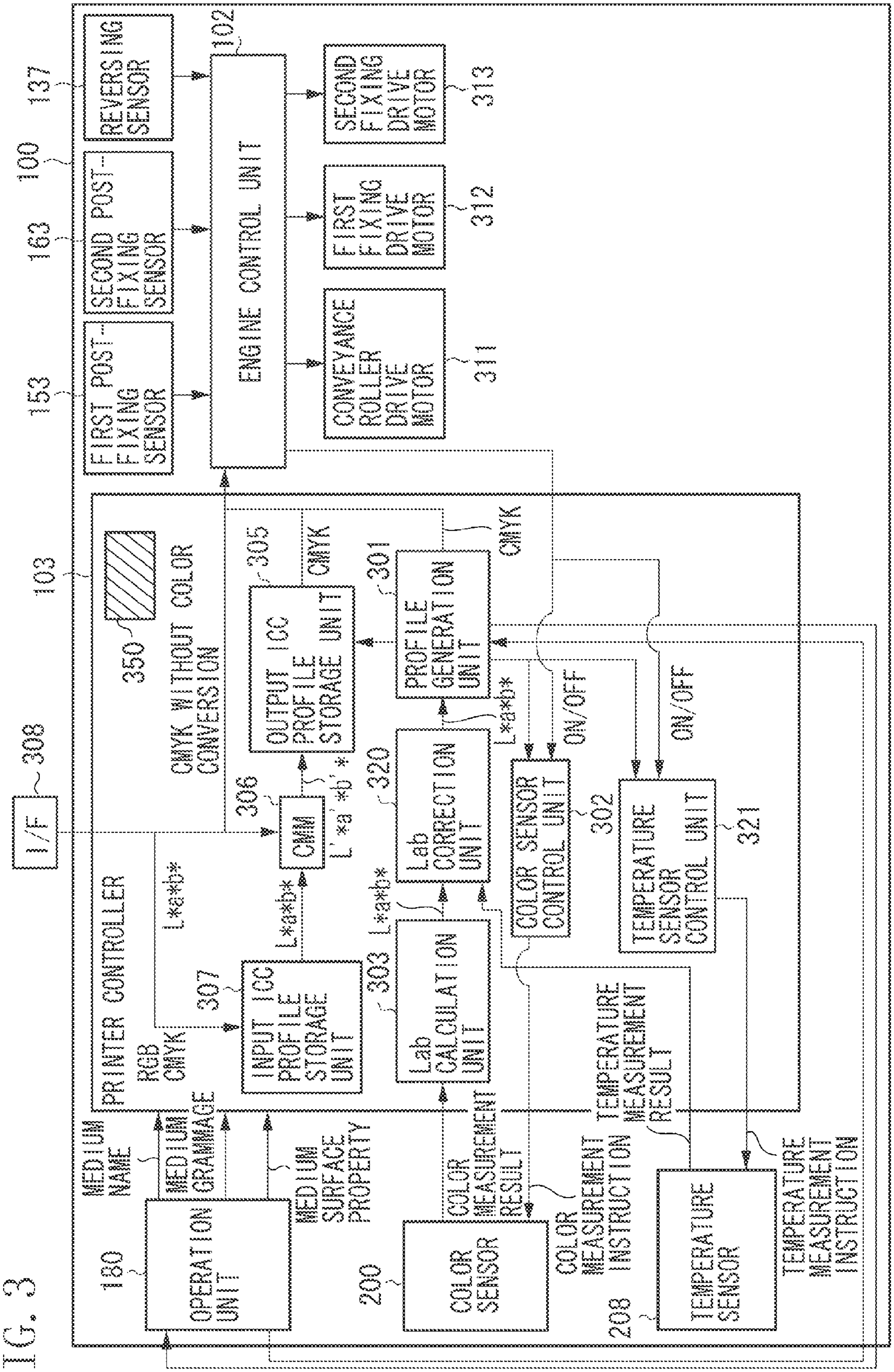

100
103
PRINTER CONTROLLER
308
I/F
180
OPERATION UNIT
MEDIUM NAME
MEDIUM GRAMMAGE
MEDIUM SURFACE PROPERTY
200
COLOR SENSOR
COLOR MEASUREMENT RESULT
COLOR MEASUREMENT INSTRUCTION
208
TEMPERATURE SENSOR
TEMPERATURE MEASUREMENT RESULT
TEMPERATURE MEASUREMENT INSTRUCTION
RGB CMYK
307
INPUT ICC PROFILE STORAGE UNIT
L*a*b*
303
Lab CALCULATION UNIT
306
CMM
L'*a'*b'*
305
OUTPUT ICC PROFILE STORAGE UNIT
CMYK
320
Lab CORRECTION UNIT
301
PROFILE GENERATION UNIT
302
COLOR SENSOR CONTROL UNIT
321
TEMPERATURE SENSOR CONTROL UNIT
ON/OFF
350
CMYK WITHOUT COLOR CONVERSION
102
ENGINE CONTROL UNIT
153
FIRST POST-FIXING SENSOR
163
SECOND POST-FIXING SENSOR
137
REVERSING SENSOR
311
CONVEYANCE ROLLER DRIVE MOTOR
312
FIRST FIXING DRIVE MOTOR
313
SECOND FIXING DRIVE MOTOR

FIG. 3

FIG. 4

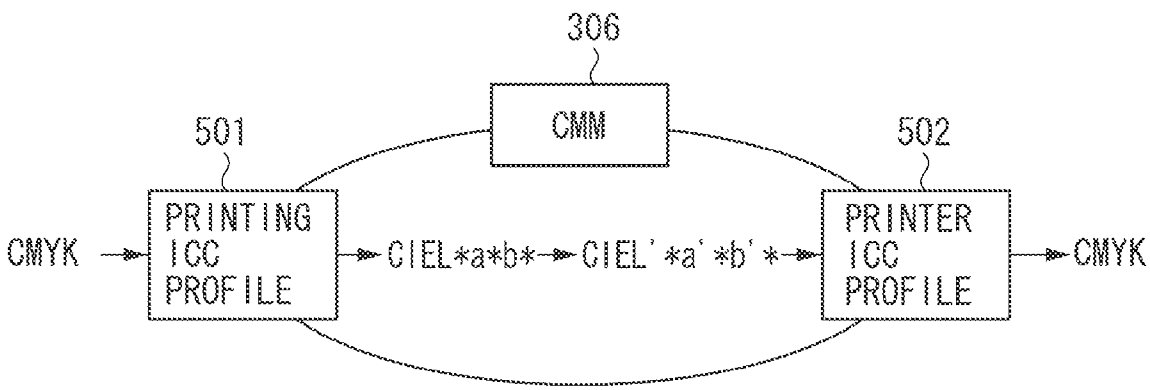

306
CMM
501
502
CMYK
PRINTING ICC PROFILE
CIEL*a*b*
CIEL'*a'*b'*
PRINTER ICC PROFILE
CMYK

FIG. 5

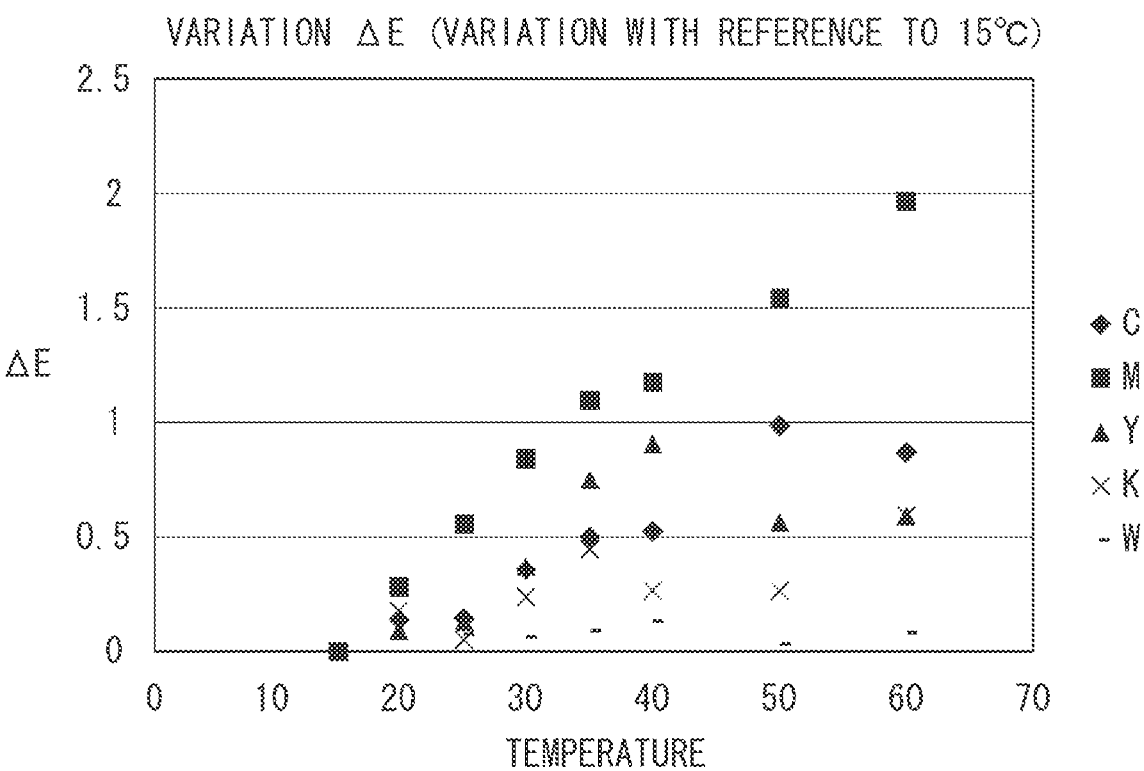

VARIATION ΔE (VARIATION WITH REFERENCE TO 15°C)
ΔE
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
TEMPERATURE
C
M
Y
K
W

FIG. 6

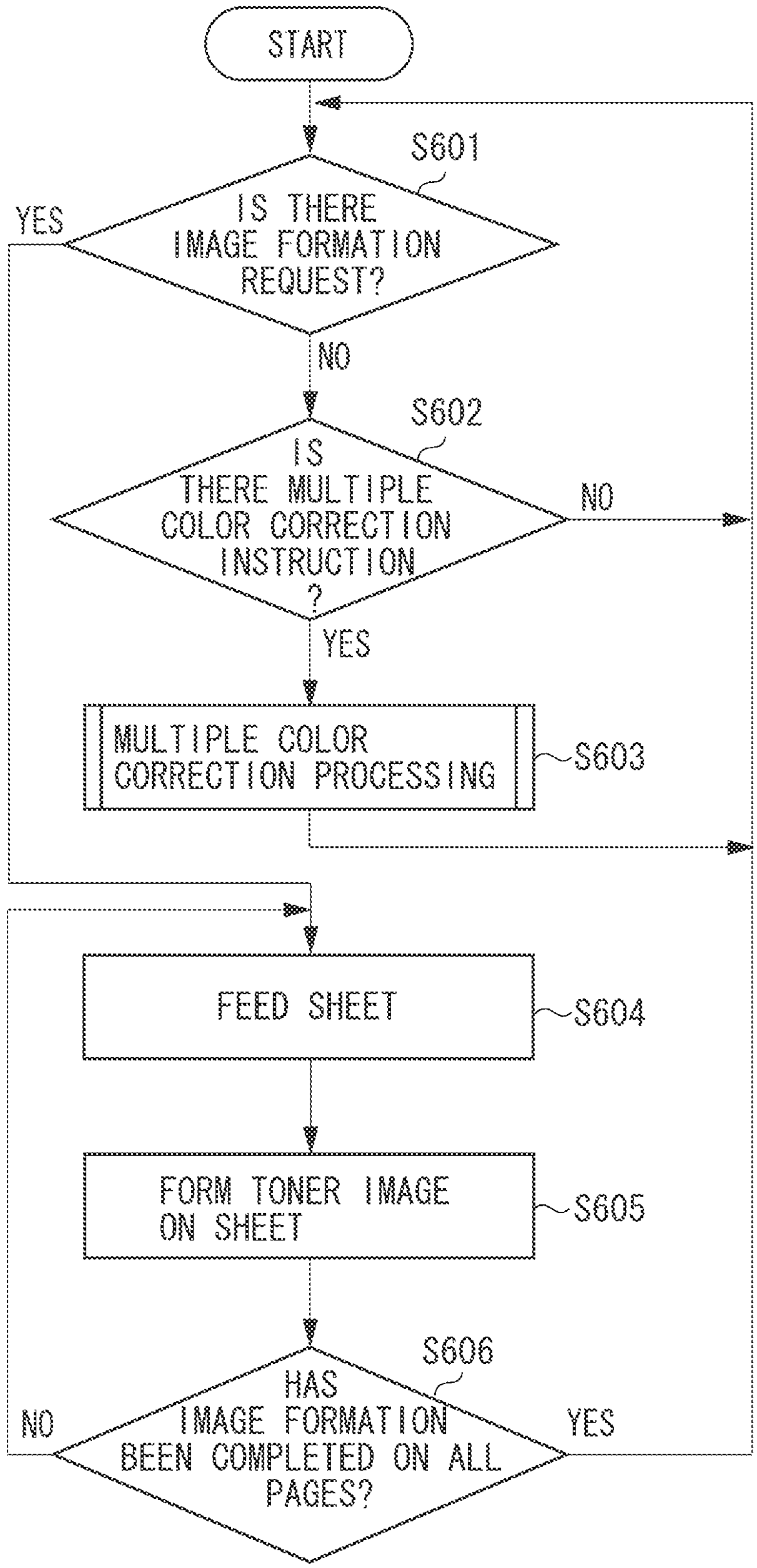

START
S601
IS THERE IMAGE FORMATION REQUEST?
YES
NO
S602
IS THERE MULTIPLE COLOR CORRECTION INSTRUCTION ?
NO
YES
MULTIPLE COLOR CORRECTION PROCESSING
S603
FEED SHEET
S604
FORM TONER IMAGE ON SHEET
S605
S606
HAS IMAGE FORMATION BEEN COMPLETED ON ALL PAGES?
NO
YES

FIG. 7

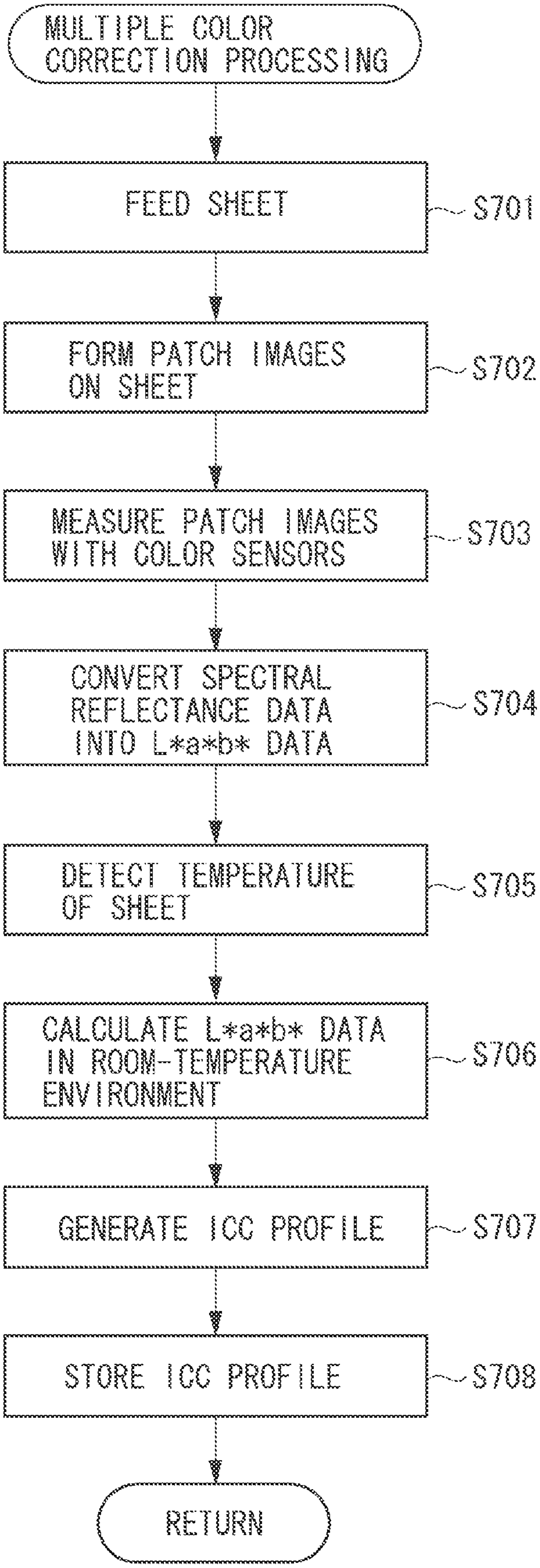

MULTIPLE COLOR CORRECTION PROCESSING
FEED SHEET
S701
FORM PATCH IMAGES ON SHEET
S702
MEASURE PATCH IMAGES WITH COLOR SENSORS
S703
CONVERT SPECTRAL REFLECTANCE DATA INTO L*a*b* DATA
S704
DETECT TEMPERATURE OF SHEET
S705
CALCULATE L*a*b* DATA IN ROOM-TEMPERATURE ENVIRONMENT
S706
GENERATE ICC PROFILE
S707
STORE ICC PROFILE
S708
RETURN

FIG. 8A

60°C			25°C ROOM-TEMPERATURE ENVIRONMENT		
L	a	b	L	a	b
54.7	-33.9	-48.0	54.6	-32.9	-48.9
47.1	71.4	-4.4	47.9	72.0	-3.3
91.2	-5.9	94.5	91.2	-6.4	94.4
20.2	-0.1	0.4	21.0	-0.1	0.4
48.4	63.2	51.8	49.1	63.4	52.2
49.7	-62.9	33.5	49.6	-62.5	33.2
20.9	25.4	-41.5	21.0	25.4	-40.9
⋮	⋮	⋮	⋮	⋮	⋮

FIG. 8B

DETECTION TEMPERATURE [°C]	CONVERSION TABLE
80~	$A_T = 80$
70~	$A_T = 70$
60~	$A_T = 60$
50~	$A_T = 50$
40~	$A_T = 40$
30~	$A_T = 30$

FIG. 9

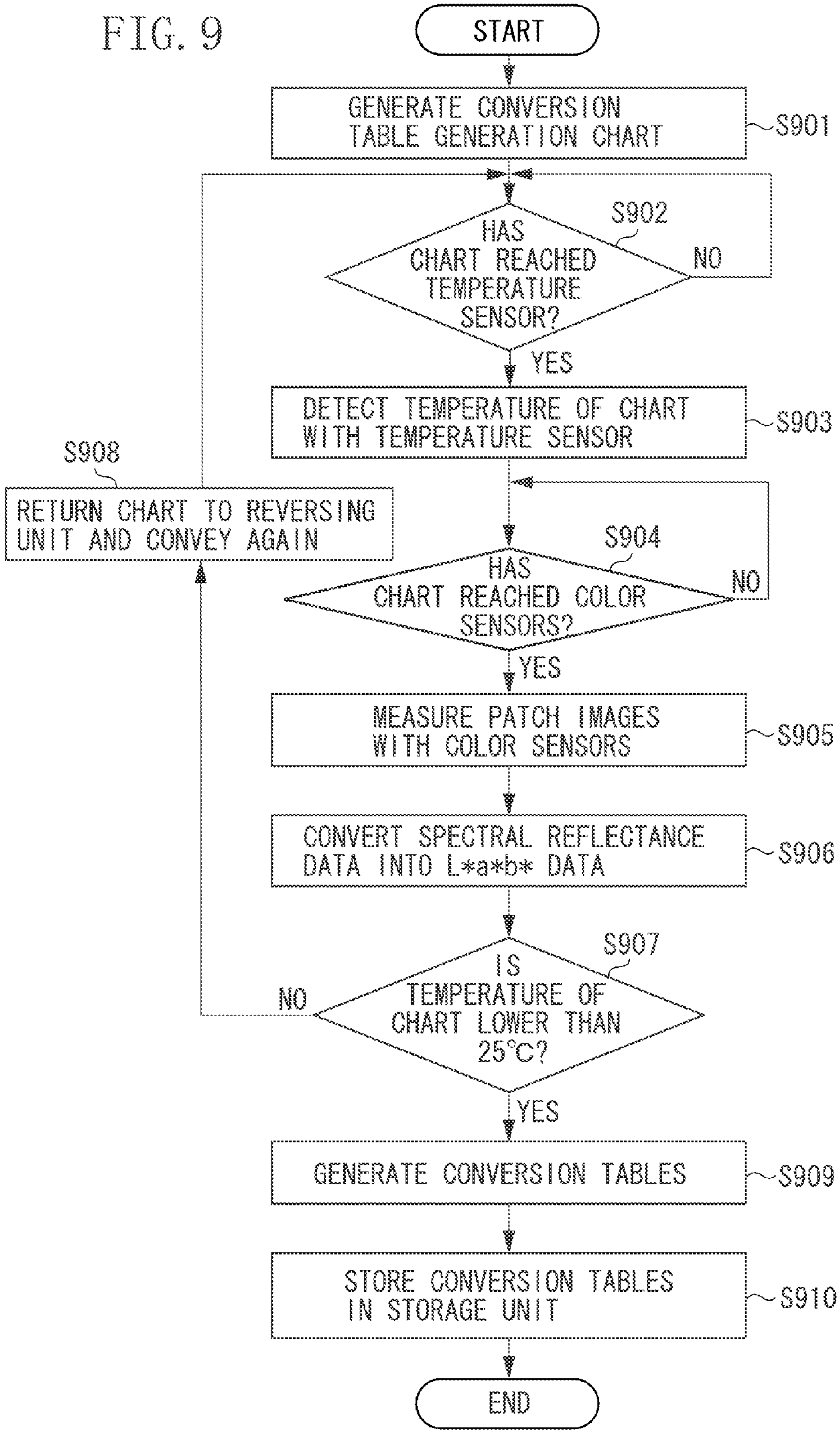

START
GENERATE CONVERSION TABLE GENERATION CHART
S901
HAS CHART REACHED TEMPERATURE SENSOR?
S902
NO
YES
DETECT TEMPERATURE OF CHART WITH TEMPERATURE SENSOR
S903
S908
RETURN CHART TO REVERSING UNIT AND CONVEY AGAIN
HAS CHART REACHED COLOR SENSORS?
S904
NO
YES
MEASURE PATCH IMAGES WITH COLOR SENSORS
S905
CONVERT SPECTRAL REFLECTANCE DATA INTO L*a*b* DATA
S906
IS TEMPERATURE OF CHART LOWER THAN 25°C?
S907
NO
YES
GENERATE CONVERSION TABLES
S909
STORE CONVERSION TABLES IN STORAGE UNIT
S910
END

IMAGE FORMING APPARATUS FOR MEASURING THE COLOR OF A MEASUREMENT IMAGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present disclosure generally relates to image forming and, more particularly, to an image forming apparatus having a function of measuring the color of a measurement image.

2. Description of the Related Art

An image forming apparatus has image qualities such as granularity, in-plane uniformity, character quality, and color reproducibility (including color stability). With the proliferation of multicolor image forming apparatuses today, the color reproducibility is sometimes said to be the most important image quality.

Humans have memories of empirically expected colors (of skin, blue sky, and metals in particular), and can get an unconformable feeling if the allowable ranges are exceeded. Such colors are called memory colors, reproducibility of which has often been demanded when outputting photographs.

Aside from photographic images, office users may feel unconformable about a color difference of document images from display monitors. Graphic arts users are pursuing color reproducibility of computer graphics (CG) images. The demand for the color reproducibility (including stability) of image forming apparatuses is thus ever increasing.

To meet the users' demand for the color reproducibility, an image forming apparatus that reads measurement images formed on a sheet with color sensors arranged on a sheet conveyance path has been discussed (for example, see Japanese Patent Application Laid-Open No. 2004-086013).

The image forming apparatus forms the measurement images on a sheet, and gives feedback to a process condition such as the amount of exposure and a developing bias based on the reading result of the measurement images by the color sensors. This enables reproduction of a certain density, graduation, and color tone.

However, according to Japanese Patent Application Laid-Open No. 2004-086013, the color sensors are arranged on a conveyance path near a fixing unit. This arouses concern about a phenomenon called "thermochromism," where the measurement images to be measured vary in color with temperature. Such a phenomenon occurs because molecular structures forming color materials such as toner and ink are changed by "heat."

To measure the measurement images inside the image forming apparatus, the color materials need to have been placed on the sheet and the color mixing needs to be completed. If the image forming apparatus uses inks as the color materials, a drying unit needs to heat and dry the measurement images before the measurement. If the image forming apparatus uses toners as the color materials, a fixing unit needs to heat and melt the toners for color mixing before the measurement. The color sensors therefore need to be arranged downstream of the drying unit or fixing unit in the conveyance direction of the sheet.

On the other hand, to constitute the image forming apparatus in a compact configuration, the conveyance path from the drying unit or fixing unit to the color sensors needs to be kept to a minimum necessary length. As a result, the sheet and the color materials heated by the drying unit or fixing unit are conveyed to the color sensors without being cooled to ordinary temperature. Sheet conveyance guides and other internal members of the image forming apparatus and the atmosphere inside also rise in temperature. This also contributes to a sheet temperature higher than ordinary temperature.

As described above, an image forming apparatus including color sensors inside can produce a measurement result different from the color in a normal environment (ordinary temperature environment) because of thermochromism.

SUMMARY OF THE INVENTION

The present disclosure is directed to an image forming apparatus that can suppress the effect of the thermochromism phenomenon where measurement images vary in color with temperature, to measure the color of the measurement images with high accuracy.

According to an aspect of the present disclosure, an image forming apparatus includes an image forming unit configured to form a measurement image on a sheet, a fixing unit configured to heat and fix the measurement image formed by the image forming unit to the sheet, a measurement unit arranged downstream of the fixing unit in a conveyance direction of the sheet and configured to measure color of the measurement image fixed by the fixing unit, a conversion unit configured to convert a measurement result of the measurement unit into a measurement result at a predetermined temperature based on conversion setting information set in advance, a setting unit configured to set a mode for generating the conversion setting information, and a generation unit configured to generate the conversion setting information by causing the image forming unit to form the measurement image on the sheet, causing the fixing unit to fix the formed measurement image, and causing the measurement unit to repeatedly measure the fixed measurement image in response to setting of the mode by the setting unit.

Further features and aspects of the present disclosure will become apparent from the following detailed description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view illustrating a structure of an image forming apparatus **100**.

FIG. **2** is a diagram illustrating a structure of a color sensor **200**.

FIG. **3** is a block diagram illustrating a system configuration of the image forming apparatus **100**.

FIG. **4** is a schematic diagram illustrating a color management environment.

FIG. **5** is a chart illustrating a tendency of color variations of respective color materials.

FIG. **6** is a flowchart illustrating an operation of the image forming apparatus **100**.

FIG. **7** is a flowchart illustrating multiple color correction processing.

FIG. **8**A is a diagram illustrating a direct mapping-based conversion table, and FIG. **8**B is a diagram illustrating conversion tables for respective sheet temperatures.

FIG. **9** is a flowchart illustrating processing for generating conversion tables.

DESCRIPTION OF THE EMBODIMENTS

<Image Forming Apparatus>

In a first exemplary embodiment, a method for solving the foregoing problem will be described by using an electrophotographic laser beam printer. Here, an electrophotographic method is used as an example of the image forming method.

However, exemplary embodiments of the present disclosure are also applicable to an inkjet printing method and a sublimation method. The inkjet printing method uses an image forming unit that forms an image on a sheet by discharging ink and a fixing unit (drying unit) that dries the ink.

FIG. **1** is a sectional view illustrating a structure of an image forming apparatus **100**. The image forming apparatus **100** includes a housing **101**. The housing **101** includes mechanisms for constituting an engine unit, and a control board accommodation unit **104**. The control board accommodation unit **104** accommodates an engine control unit **102** and a printer controller **103**. The engine control unit **102** performs control about printing processes (such as sheet feeding process) of the mechanisms. As used herein, the term "unit" generally refers to any combination of software, firmware, hardware, or other component that is used to effectuate a purpose.

As illustrated in FIG. **1**, the engine unit includes four stations **120**, **121**, **122**, and **123** corresponding to yellow (Y), magenta (M), cyan (C), and black (K), respectively. The stations **120**, **121**, **122**, and **123** are image forming units which transfer toner to a sheet **110** to form an image. The stations **120**, **121**, **122**, and **123** generally include common parts. Photosensitive drums **105** are a kind of image bearing member. Primary charging units **111** charge the photosensitive drums **105** with a uniform surface potential. Lasers **108** output laser light, by which latent images are formed on the photosensitive drums **105**. Developing units **112** develop the latent images by using color materials (toners) to form toner images. The toner images (visible images) are transferred onto an intermediate transfer member **106**. A sheet **110** is conveyed from a paper storage unit **113**. Transfer rollers **114** transfer the visible image formed on the intermediate transfer member **106** to the sheet **110**.

A fixing processing mechanism according to the present exemplary embodiment includes a first fixing device **150** and a second fixing device **160**. The first fixing device **150** applies heat and pressure to the toner images transferred to the sheet **110**, thereby fixing the toner images to the sheet **110**. The first fixing device **150** includes a fixing roller **151**, a pressure belt **152**, and a first post-fixing sensor **153**. The fixing roller **151** applies heat to the sheet **110**. The pressure belt **152** presses the sheet **110** against the fixing roller **151**. The first post-fixing sensor **153** detects the completion of fixing. The fixing roller **151** is a hollow roller and includes a heater inside.

The second fixing device **160** is arranged downstream of the first fixing device **150** in a conveyance direction of the sheet **110**. The second fixing device **160** adds gloss to the toner image on the sheet **110** fixed by the first fixing device **150** and/or ensures the fixability. Like the first fixing device **150**, the second fixing device **160** includes a fixing roller **161**, a pressure roller **162**, and a second post-fixing sensor **163**. Some types of sheets **110** need not be passed through the second fixing device **160**. In such a case, the sheets **110** are passed through a conveyance path **130**, not the second fixing device **160**, for the purpose of reducing energy consumption.

For example, a setting may be made to add a large amount of gloss to a toner image on a sheet **110**. Like thick paper, a sheet **110** may need a large amount of heat for fixing. In such cases, the sheet **110** passed through the first fixing device **150** is conveyed to the second fixing device **160**. On the other hand, if a sheet **110** is plain paper or thin paper and no setting is made to add a large amount of gloss, the sheet **110** is conveyed through the conveyance path **130** bypassing the second fixing device **160**. A flapper **131** is switched to control whether to convey the sheet **110** to the second fixing device **160** or convey the sheet **110** to bypass the second fixing device **160**.

A conveyance path switching flapper **132** is a guide member that guides the sheet **110** to either a discharge path **135** or an external discharge path **139**. Color sensors **200** and a temperature sensor **208** are arranged downstream of the second fixing device **160** in a conveyance direction of the sheet **110**. The color sensors **200** detect measurement images (hereinbelow, referred to as patch images) on the sheet **110**. In the present exemplary embodiment, four color sensors **200** are juxtaposed in a direction orthogonal to the conveyance direction of the sheet **110**, and can detect four rows of patch images. If an instruction for color detection is given from an operation unit **180**, the engine control unit **102** performs a density adjustment, a gradation adjustment, and multiple color correction processing. The temperature sensor **208**, serving as a temperature detection unit, is a sensor for detecting the temperature of the sheet **110**. For the density adjustment and the gradation adjustment, the color sensors **200** measure the densities of monochromatic measurement images. For a multiple color adjustment, the color sensors **200** measure the densities of measurement images colored by superposing a plurality of colors.

A reversing sensor **137** is arranged on the discharge path **135**. A leading edge of the sheet **110** measured by the color sensors **200** is conveyed past the reversing sensor **137** to a reversing unit **136**. When the reversing sensor **137** detects a trailing edge of the sheet **110**, the conveyance direction of the sheet **110** is switched. A conveyance path switching flapper **133** is a guide member that guides the sheet **110** to either a conveyance path **138** for two-sided image formation or the discharge path **135**. A conveyance path switching flapper **134** is a guide member that guides the sheet **110** to the external discharge path **139**. The sheet **110** conveyed through the discharge path **139** is discharged to outside the image forming apparatus **100**.

<Color Sensor>

FIG. **2** is a diagram illustrating a structure of the color sensor **200**. The color sensor **200** each includes a white light-emitting diode (LED) **201**, a diffraction grating **202**, a line sensor **203**, a calculation unit **204**, and a memory **205**. The white LED **201** is a light emitting element which irradiates a patch image **220** on a sheet **110** with light. The diffraction grating **202** separates the light reflected from the patch image **220** by wavelength. The line sensor **203** is a light detection device including n light receiving elements that detect the light separated by the diffraction grating **202** by wavelength. The calculation unit **204** performs various calculations on the light intensity values of pixels detected by the line sensor **203**.

The memory **205** stores various types of data for the calculation unit **204** to use. For example, the calculation unit **204** includes a spectral calculation unit which performs spectral calculations on the light intensity values and a Lab calculation unit which calculates Lab values. The color sensor **200** may further include a lens **206** which condenses the light emitted from the white LED **201** onto a patch image **220** on the sheet **110** and/or condenses the light reflected from the patch image **200** onto the diffraction grating **202**.

<Profile>

To perform the multiple color correction processing, the image forming apparatus **100** generates a profile from the detection results of the patch images including multiple colors. Using the profile, the image forming apparatus **100** converts an input image into an output image. The multiple color patch images are patch images formed by superposing a plurality of colors of toners.

International Color Consortium (ICC) profiles have recently been accepted widely in the market. The present exemplary embodiment uses an ICC profile as a profile for providing excellent color reproducibility. However, the present disclosure is not inapplicable without an ICC profile. Exemplary embodiments of the present disclosure may be applied to a color rendering dictionary (CRD) which has been employed for level 2 and above of PostScript proposed by Adobe Systems, Inc., and a color separation table in Photoshop™.

When a customer engineer replaces parts, before the image forming apparatus **100** performs a job that needs high color matching accuracy, or when a user wants to know the color of a final output product at the design stage, the user operates the operation unit **180** to issue an instruction for processing for generating a color profile.

The processing for generating a color profile is performed by the printer controller **103** illustrated in the block diagram of FIG. **3**. The printer controller **103** includes a central processing unit (CPU). The CPU reads a program for performing a flowchart to be described below from a storage unit **350** and executes the program. For easy understanding of the processing performed by the printer controller **103**, FIG. **3** illustrates the interior of the printer controller **103** by using blocks.

When the operation unit **180** accepts a profile generation instruction from the user, the operation unit **180** issues an instruction to generate a profile to a profile generation unit **301**. Based on the instruction, the profile generation unit **301** outputs data expressing a CMYK color chart that is an International Organization for Standardization (ISO) 12642 test form to the engine control unit **102** not via a profile. The profile generation unit **301** transmits a measurement instruction to a color sensor control unit **302**. The engine control unit **102** controls the image forming apparatus **100** to perform processes such as charging, exposure, development, transfer, and fixing. As a result, an ISO 12642 test form is formed on a sheet **110**.

The engine control unit **102** controls a conveyance roller drive motor **311**. The conveyance roller drive motor **311** drives conveyance rollers for conveying the sheet **110**. The engine control unit **102** further controls a first fixing drive motor **312** for driving the first fixing device **150** and a second fixing drive motor **313** for driving the second fixing device **160**.

The color sensor control unit **302** controls the color sensors **200** to measure the ISO 12642 test form. The color sensors **200** output spectral reflectance data that is the measurement result to a Lab calculation unit **303** of the printer controller **103**. The Lab calculation unit **303** converts the spectral reflectance data into color value data (L*a*b* data) and outputs the L*a*b* data to a Lab correction unit **320**.

A temperature sensor control unit **321** controls the temperature sensor **208** to detect the temperature of the sheet **110** according to an ON/OFF signal from the engine control unit **102**. The Lab correction unit **320** corrects the L*a*b* data received from the Lab calculation unit **303** according to the detection result of the temperature sensor **208**, and outputs the corrected L*a*b* data to the profile generation unit **301**. The Lab calculation unit **303** may convert the spectral reflectance data into an International Commission on Illumination (CIE) 1931 XYZ color system which uses device-independent color space signals.

The profile generation unit **301** generates an output ICC profile from the relationship between the CMYK color signals (data) output to the engine control unit **102** and the L*a*b* data input from the Lab calculation unit **303**. The profile generation unit **301** stores the generated output ICC profile in an output ICC profile storage unit **305**.

The ISO 12642 test form includes patches of CMYK color signals covering a color reproduction range that can be output by a typical copying machine. The profile generation unit **301** generates a color conversion table from the relationship between the color signal values and the measured L*a*b* values. In other words, the profile generation unit **301** generates a CMYK-to-Lab conversion table. Based on the conversion table, the profile generation unit **301** generates an inverse conversion table.

Accepting a profile generation instruction from a host computer through an interface (I/F) **308**, the profile generation unit **301** outputs the generated output ICC profile to the host computer through the I/F **308**. The host computer can performs color conversion corresponding to the ICC profile on an application program or programs.

Color Conversion Processing

In color conversion for ordinary color output, an image signal assuming RGB (red, green, blue) signal values or Japan Color or other standard printing CMYK signal values may be input from a scanner unit via the I/F **308**. Such an image signal is transmitted to an input ICC profile storage unit **307** intended for external input. The input ICC profile storage unit **307** performs an RGB-to-L*a*b* or CMYK-to-L*a*b* conversion according to the image signal input from the I/F **308**. The input ICC profile storage unit **307** stores an input ICC profile including a plurality of lookup tables (LUTs).

Examples of the LUTs include a one-dimensional LUT for controlling a gamma of the input signal, a multiple color LUT called direct mapping, and a one-dimensional LUT for controlling the gamma of generated conversion data. Using such LUTs, the input image signal is converted from a device-depended color space into device-independent L*a*b* data.

The image data converted into L*a*b*coordinates is input to a color management module (CMM) **306**. The CMM **306** performs various color conversions. For example, the CMM **306** performs a gamut conversion to map mismatches between a reading color space of the scanner unit serving as an input device and an output color reproduction range of the image forming apparatus **100** serving as an output device. The CMM **306** further performs color conversion to adjust a mismatch between the type of the light source at the time of input and the type of the light source when observing the output product (also referred to as a mismatch between color temperature settings).

In such a manner, the CMM **306** converts the L*a*b* data into L'*a'*b'* data, and outputs the L'*a'*b'* data to the output ICC profile storage unit **305**. The output ICC profile storage unit **305** contains the ICC profile generated by measurement. By using the generated new ICC profile, the output ICC profile storage unit **305** performs color conversion to convert the L'*a'*b'* data into CMYK signals dependent on the output device, and outputs the CMYK signals to the engine control unit **102**.

In FIG. **3**, the CMM **306** is separated into the input ICC profile storage unit **307** and the output ICC profile storage unit **305**. In fact, as illustrated in FIG. **4**, the CMM **306** refers to a module that is in charge of color management. The module performs color conversion by using an input profile (printing ICC profile **501**) and an output profile (printer ICC profile **502**).

Color Characteristics of Thermochromism

Next, thermochromism characteristics of respective colors will be described. When molecular structures forming a color material such as toner and ink are thermally changed, the molecular structures vary in color due to a change in the light reflection and absorption characteristics. FIG. **5** illustrates the results of an experiment that was performed to examine the color variations. As illustrated in FIG. **5**, the color materials were found to have different tendencies of color variation. The horizontal axis of FIG. **5** indicates the temperature of the patch image. The vertical axis indicates a variation ΔE with reference to 15° C.

ΔE can be expressed by a three-dimensional distance between two points (L1,a1,b1) and (L2,a2,b2) in the L*a*B* color space defined by CIE. The three-dimensional distance is given by the following equation:

$$\Delta E=\sqrt{(L1-L2)^2+(a1-a2)^2+(b1-b2)^2} \quad (1)$$

In FIG. **5**, C represents 100% cyan, M 100% magenta, Y 100% yellow, K 100% black, and W paper white. As illustrated in the chart, magenta has particularly poor thermochromism characteristics.

<Thermochromism Compatible Technique>

As an index of color matching accuracy and color stability, the color matching accuracy standard described in ISO 12647-7 (IT8.7/4 (ISO 12642:1617 patch) [4.2.2]) specifies average ΔE of 4.0. According to the reproducibility [4.2.3] (i.e., the stability standard), each patch is specified to have ΔE≤1.5. To satisfy such a condition, the color sensors **200** desirably have a detection accuracy of ΔE≤1.0.

In the present exemplary embodiment, when the color sensors **200** measure patch images heated by the fixing device(s), the printer controller **103** corrects the color values output from the color sensors **200** to calculate color values in an ordinary temperature environment. Even if the patch images vary in color due to thermochromism, the color values of the patch images can thus be detected with high accuracy. Processing for that purpose is described in detail below.

FIG. **6** is a flowchart illustrating an operation of the image forming apparatus **100**. The flowchart is performed by the printer controller **103**. In step S**601**, the printer controller **103** determines whether there is an image formation request from the operation unit **180** and whether there is an image formation request from the host computer via the I/F **308**.

If there is no image formation request (NO in step S**601**), then in step S**602**, the printer controller **103** determines whether there is a multiple color correction instruction from the operation unit **180**. If there is a multiple color correction instruction (YES in step S**602**), then in step S**603**, the printer controller **103** performs the multiple color correction processing. The multiple color correction processing will be described below with reference to FIG. **7**. If there is no multiple color correction instruction (NO in step S**602**), the printer controller **103** returns to step S**601**.

If, in step S**601**, it is determined that there is an image formation request (YES in step S**601**), then in step S**604**, the printer controller **103** causes the image forming apparatus **100** to feed a sheet **110** from the paper storage unit **113**. In step S**605**, the image forming apparatus **100** forms a toner image on the sheet **110**. In step S**606**, the printer controller **103** determines whether the image formation has been completed on all the pages. If the image formation has been completed on all the pages (YES in step S**606**), the printer controller **103** returns to step S**601**. If the image formation has not been completed on all the pages (NO in step S**606**), the printer controller **103** returns to step S**604** to form an image on the next page.

FIG. **7** is a flowchart illustrating multiple color correction processing. The flowchart is performed by the printer controller **103**. In step S**701**, the printer controller **103** causes the image forming apparatus **100** to feed a sheet **110** from the paper storage unit **113**. In step S**702**, the image forming apparatus **100** forms the patch images on the sheet **110**. If the sheet **110** has reached the color sensors **200**, then in step S**703**, the printer controller **103** causes the color sensors **200** to measure the patch images. The color sensors **200** output spectral reflectance data on the patch images to the printer controller **103**.

In step S**704**, the printer controller **103** converts the spectral reflectance data into color value data (L*a*b* data). In step S**705**, the printer controller **103** causes the temperature sensor **208** to detect the temperature T of the sheet **110**. In step S**706**, the printer controller **103** calculates the L*a*b* data in the ordinary temperature environment by using the L*a*b* data converted in step S**704** and the temperature T of the sheet **110** detected in step S**705**. The calculation method will be described in detail below. In the present exemplary embodiment, the ordinary temperature environment is set at a predetermined temperature (25° C.).

In step S**707**, the printer controller **103** generates an ICC profile by the foregoing processing based on the L*a*b* data calculated in step S**706**. In step S**708**, the printer controller **103** stores the ICC profile in the output ICC profile storage unit **305**. The processing then returns to the foregoing step S**601**.

FIG. **8**A illustrates a direct mapping-based conversion table of L*a*b* data from 60° C. to 25° C. (ordinary temperature environment). FIG. **8**B illustrates a conversion table for respective sheet temperatures. The processing performed in step S**706** will be specifically described with reference to FIGS. **8**A and **8**B.

The sheet **110** having just passed through the fixing device(s) has a high temperature due to the heat given by the fixing device(s). In such a state, the color sensors **200** detect the patch images, and the Lab calculation unit **303** calculates the L*a*b* data from the detection result.

Suppose that the sheet **110** has a temperature of 60° C. when the patch images are detected by the color sensors **200**. In such a case, the L*a*b* data calculated by the Lab calculation unit **303** at 60° C. includes errors with respect to the L*a*b* data at 25° C., the ordinary temperature environment.

The Lab correction unit **320** then corrects the L*a*b* data by using the detection temperature T of the temperature sensor **208** to calculate the L*a*b* data in the ordinary temperature environment. Specifically, the Lab correction unit **320** corrects the L*a*b* data by using a direct mapping-based conversion table for converting the Lab color space at 60° C. into the Lab color space in the ordinary temperature environment (25° C.) as illustrated in FIG. **8**A.

As illustrated in FIG. **8**B, the conversion table has been determined for respective ranges of the detection temperature T of the temperature sensor **208**. The specific method for generating the conversion table will be described below. The conversion table illustrated in FIG. **8**A is the conversion table $A_{T\text{-}60}$. Such conversion tables are stored in the storage unit **350**. According to the detection result of the temperature sensor **208**, the Lab correction unit **320** reads a conversion table corresponding to the detection temperature T and uses the conversion table for correction.

While the present exemplary embodiment deals with the direct mapping-based conversion method using conversion tables as conversion setting information, the conversion method is not limited thereto. For example, conversion matrices used for a typical color space correction method may be used as the conversion setting information.

In step S**705** in the present exemplary embodiment, the temperature T of the sheet **110** is detected by using the temperature sensor **208**. However, the image forming apparatus **100** need not necessarily include the temperature sensor **208**.

In such a case, the printer controller **103** may calculate the temperature from various conditions for performing an image forming operation.

Specifically, the printer controller **103** calculates the temperature of the sheet **110** at the time of color detection based on the type of the sheet **110** and a fixing mode which are input from the operation unit **180**. Possible fixing modes include a normal mode using only the first fixing device **150** and a gloss mode using both the first fixing device **150** and the second fixing device **160**. The printer controller **103** refers to a temperature calculation table set in advance and calculates the temperature. Table 1 illustrates the temperature calculation table, which is stored in the storage unit **350** in advance.

TABLE 1

		Thin paper	Plain paper	Thick paper 1	Thick paper 2
Fixing mode	Normal mode	45° C.	50° C.	62° C.	72° C.
	Gloss mode	47° C.	55° C.	65° C.	75° C.

The fixing modes will be described. The normal mode uses only the first fixing device **150**. The gloss mode uses both the first fixing device **150** and the second fixing device **160** for a fixing operation. The sheet **110** thus has a higher temperature in the gloss mode. The temperatures of the fixing devices **150** and **160** for thick papers are set to be higher than for thin paper. The thick papers retain a greater amount of heat, and thus the thick papers are higher than the thin paper in temperature.

Based on the calculation of the temperature of the sheet **110**, the Lab correction unit **320** can correct the L*a*b* data to reduce the thermochromism effect.

<Generation of Conversion Tables>

In the present exemplary embodiment, the printer control **103** converts the L*a*b data actually measured by the color sensors **200** into the L*a*b* in the ordinary temperature environment by using the conversion tables illustrated in FIGS. **8**A and **8**B.

The color sensors **200** may have individual difference. Various paper types also need to be taken into consideration. Thus, setting the relationship between the temperatures and the color values thus has only a limited accuracy. Therefore, in the present exemplary embodiment, the relationship between the temperatures and the color values (L*a*b* data) is actually measured to generate conversion tables for improved accuracy.

FIG. **9** is a flowchart illustrating processing for generating the conversion tables illustrated in FIGS. **8**A and **8**B. The flowchart is performed by the printer controller **103** based on the setting of a conversion table generation mode from the operation unit **180**. The engine control unit **102** controls the image forming apparatus **100** based on instructions from the printer controller **103**.

In step S**901**, the printer controller **103** feeds a sheet **110** from the paper storage unit **113** and forms a plurality of multiple color patch images on the sheet **110** to generate a conversion table generation chart (hereinbelow, referred to simply as a chart). The formed multiple color patch images include patch images in 16 levels (Y)×16 levels (M)×16 levels (C)=4096 colors. The generated chart is conveyed to the reversing unit **136** before reversed in the traveling direction and conveyed toward the temperature sensor **208** and the color sensors **200**.

In step S**902**, the printer controller **103** waits until the chart reaches the temperature sensor **208**. The printer controller **103** determines whether the chart has reached the temperature sensor **208** by measuring the time elapsed since the reversing sensor **137** detected the chart. If it is determined that the chart has reached the temperature sensor **208** (YES in step S**902**), then in step S**903**, the printer controller **103** causes the temperature sensor **208** to detect the temperature of the chart.

In step S**904**, the printer controller **103** waits until the chart reaches the color sensors **200**. The printer controller **103** similarly determines whether the chart has reached the color sensors **200** by measuring the time elapsed since the reversing sensor **137** has detected the chart. If it is determined that the chart has reached the color sensors **200** (YES in step S**904**), then in step S**905**, the printer controller **103** causes the color sensors **200** to measure the patch images on the chart.

In step S**905**, the color sensors **200** output spectral reflectance data on the patch images to the printer controller **103**. In step S**906**, the printer controller **103** converts the spectral reflectance data into color value data (L*a*b* data).

In step S**907**, the printer controller **103** determines whether the temperature of the chart measured in step S**903** is lower than 25° C. If the temperature of the patch image is higher than or equal to 25° C. (NO in step S**907**), then in step S**908**, the printer controller **103** returns the chart to the reversing unit **136** and conveys the chart toward the temperature sensor **208** and the color sensors **200** again.

The processing then proceeds to step S**902** to measure the patch images at a temperature lower than that in the previous measurement. In such a manner, the reversal conveyance, temperature measurement, and color value measurement are repeated to dissipate (cool) the heat of the chart and lower the temperature. The printer controller **103** repeats such operations until the chart falls below 25° C., whereby the relationship between the temperatures and the color values of the same chart is actually measured.

If, in step S**907**, it is determined that the temperature of the chart is lower than 25° C. (YES in step S**907**), then in step S**909**, the printer controller **103** generates the conversion tables illustrated in FIGS. **8**A and **8**B from the L*a*b* data measured at respective temperatures. Specifically, the L*a*b* data of the patch images measured corresponds to the left half of the conversion table illustrated in FIG. **8**A. The L*a*b* data of the patch images in the ordinary temperature environment, i.e., the L*a*b* data listed in the right half of the conversion table of FIG. **8**A is the L*a*b* data last measured in step S**906**.

As illustrated in FIG. **8**B, the printer controller **103** generates the conversion tables for the respective temperatures measured by the temperature sensor **208**. In the example illustrated in FIG. **8**B, the conversion tables are generated at intervals of 10° C. However, the conversion tables generated by actual measurements are not necessarily at such regular intervals. In such a case, the detection temperatures in the left field of FIG. **8**B may be appropriately modified based on the measured temperatures. In step S**910**, the printer controller **103** stores the generated conversion tables in the storage unit **350**. The printer controller **103** then ends the processing.

As described above, the printer controller **103** generates the conversion tables for converting the L*a*b data measured from the patch images at higher temperatures in the ordinary temperature environment into the L*a*b* data in the ordinary temperature environment. This can suppress the effect of the thermochromism phenomenon with high accuracy.

In the first exemplary embodiment, the printer controller **103** generates the conversion tables based on actual measurements, and corrects the color values measured by the color sensors **200**. When generating the conversion tables, the printer controller **103** repeats measuring the color values of the patch images until the temperature of the chart falls below 25° C. However, if the initially measured temperature of the chart is not high at that time, the printer controller **103** cannot generate conversion tables for a wide temperature range as illustrated in FIG. **8**B.

When the image forming apparatus **100** is powered on after having been left idle for several hours, the guide members constituting the conveyance paths are often cold. The cold guide members can make contact with the heated and fixed chart to lower the temperature of the chart.

The image forming apparatus **100** was actually left idle for seven hours or more before powered on. The temperature of the chart rose only up to 50° C. If conversion tables are generated in such an environment based on the actual measurements like the first exemplary embodiment, the generated conversion tables can only cover the range of 25° C. to 50° C. It will be understood that high accuracy is obtained only within the range. At temperatures above 50° C., the color values of the patch images cannot be measured with high accuracy.

The instruction to generate an ICC profile, i.e., the instruction for the multiple color correction processing may be given any time at any temperature. The conversion tables are therefore desirably generated to cover a wide temperature range.

In a second exemplary embodiment, the conveyance paths from the fixing devices **150** and **160** to the color sensors **200** are preheated before the output of the conversion tale generation chart. Specifically, sheets **110** fed from the paper storage unit **113** are heated by the first and second fixing devices **150** and **160** and conveyed through the conveyance paths to the color sensors **200** to warm the conveyance paths. This can increase the temperature of the conveyance paths before the measurement of the patch images by the color sensors **200** as compared to when the image forming apparatus **100** is powered on. As a result, the temperature range at the time of generating the conversion tables can be widened.

In the present exemplary embodiment, the image forming apparatus **100**, which has received a conversion table generation instruction, passes 100 sheets **110** in a two-sided printing mode. In the two-sided printing mode, the sheets **110** pass the reversing unit **136** to preheat the conveyance guides near the color sensors **200**. The two-sided printing mode is used because the discharged sheets **110** have higher temperatures than those in a one-sided printing mode. The two-sided printed sheets **110** are discharged in a reverse discharge mode. In other words, the sheets **110** are conveyed to the reversing unit **136** before reversed in the traveling direction and discharged reversed.

Through such control, the image forming apparatus **100** can generate conversion tables over a wide temperature range (from 80° C. to 25° C.). The two-sided printed sheets **110** may be left blank on both sides. The sheets **110** may be printed with solid black images on both sides. Since both sheets have the effect of increasing the temperature of the conveyance paths, the present exemplary embodiment is thus not limited to either of the sheets. The greater the amount of toner, the less the heat dissipates. The sheets printed with toner are thus generally more favorable than the blank sheets, whereas the toner is consumed accordingly. Which sheets to use may be selected as appropriate in view of the advantages and disadvantages.

While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims priority from Japanese Patent Application No. 2012-234025 filed Oct. 23, 2012, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An image forming apparatus comprising:
- an image forming unit configured to form a measurement image on a sheet;
- a fixing unit configured to heat the measurement image formed on the sheet to fix the measurement image to the sheet;
- a measurement unit arranged downstream of the fixing unit in a conveyance direction of the sheet and configured to measure color of the measurement image fixed by the fixing unit;
- a storage unit configured to store a plurality of pieces of conversion setting information each of which corresponds to one of a plurality of temperatures;
- a selecting unit configured to select a piece of conversion setting information from among the plurality of pieces of conversion setting information;
- a conversion unit configured to convert a measurement result of the measurement unit into a measurement result at a predetermined temperature based on the selected conversion setting information; and
- a control unit configured to cause the image forming unit to form the measurement image on the sheet, and cause the fixing unit to fix the formed measurement image onto the sheet, and
- wherein, when the sheet passed through the fixing unit is firstly conveyed to a measurement position, the control unit causes the measurement unit to measure a color of the measurement image and first measurement color data is obtained,
- after that, the control unit causes the measurement unit to measure a color of the measurement image under a condition that a temperature of the sheet is lower than the predetermined temperature, and second measurement color data is obtained; and
- a generation unit configured to generate conversion setting information based on the first and second measurement color data and store the generated conversion setting information in the storage unit.

2. The image forming apparatus according to claim **1**, further comprising a temperature detection unit configured to detect a temperature of the sheet,
- wherein the conversion unit is configured to convert the measurement result of the measurement unit into a measurement result in an ordinary temperature environment by using the conversion setting information corresponding to the temperature detected by the temperature detection unit.

3. The image forming apparatus according to claim **1**, further comprising a temperature calculation unit configured to calculate a temperature of the sheet,
- wherein the conversion unit is configured to convert the measurement result of the measurement unit into a measurement result in an ordinary temperature environment by using the conversion setting information corresponding to the temperature calculated by the temperature calculation unit.

4. The image forming apparatus according to claim **3**, wherein the temperature calculation unit is configured to calculate the temperature of the sheet based on a type of the sheet.

5. The image forming apparatus according to claim 3,
wherein the fixing unit includes a first fixing device and a second fixing device arranged downstream of the first fixing device, and
wherein the temperature calculation unit is configured to calculate the temperature of the sheet based on whether to use both the first and second fixing devices or use either one of the first and second fixing devices.

6. The image forming apparatus according to claim 1, further comprising a preheating unit configured to preheat a conveyance path leading from the fixing unit to the measurement unit before the generation unit causes the measurement unit to measure the measurement image to generate the conversion setting information.

7. The image forming apparatus according to claim 6, wherein the preheating unit is configured to preheat the conveyance path leading from the fixing unit to the measurement unit by using heat of a sheet that has passed through the fixing unit.

8. The image forming apparatus according to claim 7, wherein the preheating unit is configured to preheat the conveyance path by setting a two-sided printing mode where images are formed on both sides of a sheet and a reverse discharge mode where the sheet is discharged reversed, and performing image formation.

9. The image forming apparatus according to claim 1, wherein the measurement unit is configured to measure an amount of light reflected from the measurement image in each wavelength range.

10. The image forming apparatus according to claim 1, further comprising a first calculation unit configured to calculate spectral reflectance of the measurement image based on the measurement result of the measurement image by the measurement unit.

11. The image forming apparatus according to claim 10, further comprising a second calculation unit configured to calculate a color value from the spectral reflectance.

12. The image forming apparatus according to claim 11, further comprising a second generation unit configured to generate a color correction table based on a calculation result of the second calculation unit.

13. The image forming apparatus according to claim 12, wherein the color correction table is an ICC (International Color Consortium) profile.

14. The image forming apparatus according to claim 13, further comprising a storage unit configured to store the ICC profile generated by the second generation unit.

15. The image forming apparatus according to claim 1, wherein the image forming unit is configured to form a monochromatic measurement image at a time of density measurement, and form a measurement image produced by superposing a plurality of colors at a time of color measurement.

16. The image forming apparatus according to claim 1, wherein the predetermined temperature is 25° C.

17. The image forming apparatus according to claim 1, wherein the setting unit is an operation unit configured to accept an operation input from a user.

18. The image forming apparatus according to claim 1,
wherein the image forming unit is a unit configured to form the image by transferring toner to the sheet, and
wherein the fixing unit is a unit configured to heat and fix the toner to the sheet.

19. The image forming apparatus according to claim 1, wherein the image forming unit is a unit configured to form the image on the sheet by discharging ink, and
wherein the fixing unit is a drying unit configured to dry the ink.

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